Antenna Modeling in Software

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Why Model an Antenna?

- It’s very difficult to assemble, adjust, modify, and optimize a physical antenna.
- It’s very difficult or time consuming to measure the gain, pattern, and efficiency of a real antenna.
- Antenna models can tell us about efficiency, pattern, gain, and input impedance.
- It’s FAST. We can iterate through a lot of models and quickly focus on those that are most useful.
  - Properly done, it’s quite accurate.
  - Improperly done, it can generate complete nonsense.

Where does it come from?

- Original software was called BRACT, superseded by Antenna Modeling Program (AMP), developed 1971.
- Numerical Electromagnetics Code (NEC-2) developed at Lawrence Livermore Lab – 1981.
  - Sponsored by Naval Ocean Systems Center.
  - FORTRAN source code is in the public domain.
- NEC-4 also developed at LLL.
  - Not in the public domain. Requires a license from LLL. $250.

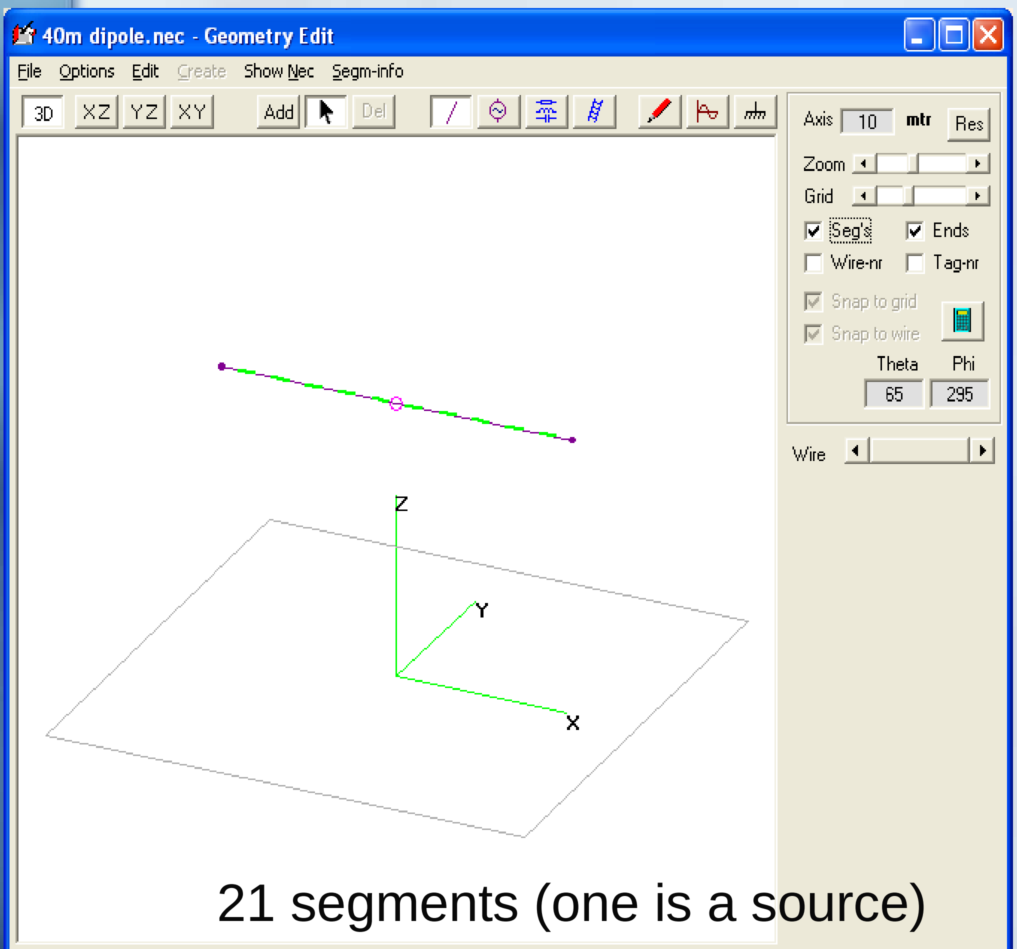
How does it work?

- Wire antennas are modeled using Electric-Field Integral Equation (EFIE).
- Antenna is broken up into small pieces called *segments*.
- Each segment has current in it
  - Due to sources feeding power to the antenna, plus
  - Currents induced by an impinging field from neighboring segments (and possibly external sources).
- Current in each segment causes radiation.
- The antenna pattern is the sum of all the fields contributed by each segment of the antenna.

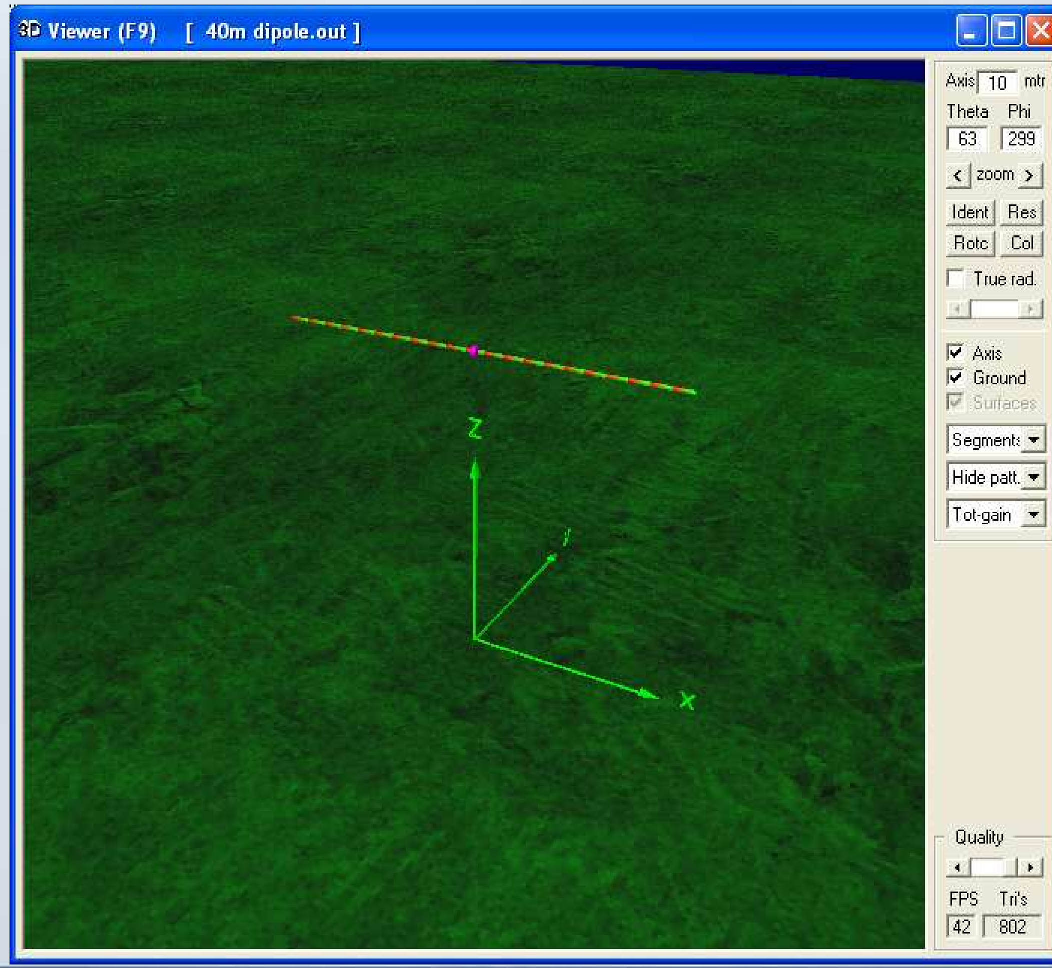
Coordinates

Rectangular (data entry) and Polar (pattern plots)

- Z = up/down X = left/right Y = front/back
- Theta θ = elevation, Phi φ = azimuth



21 segments (one is a source)

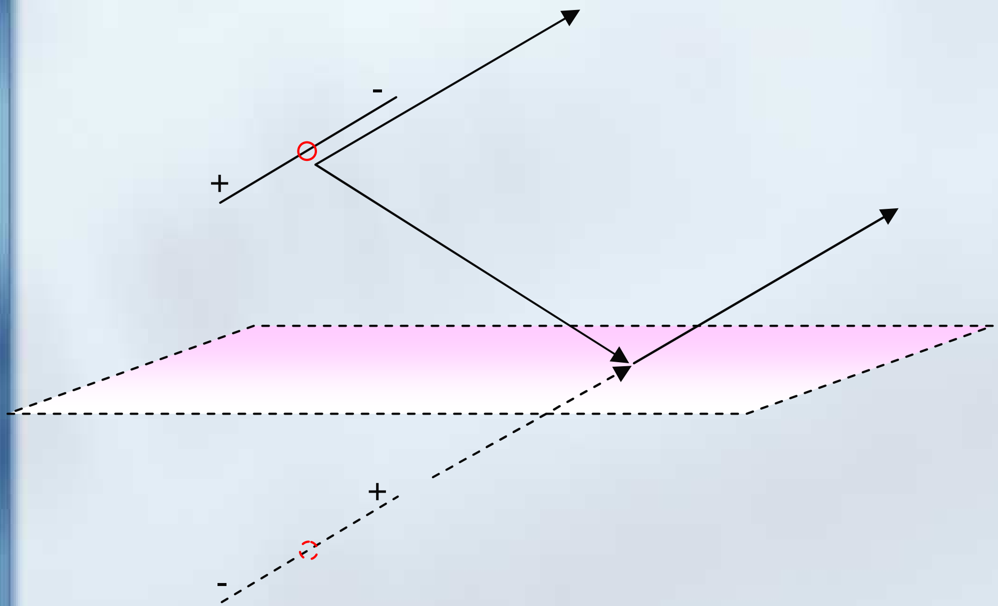


Ground

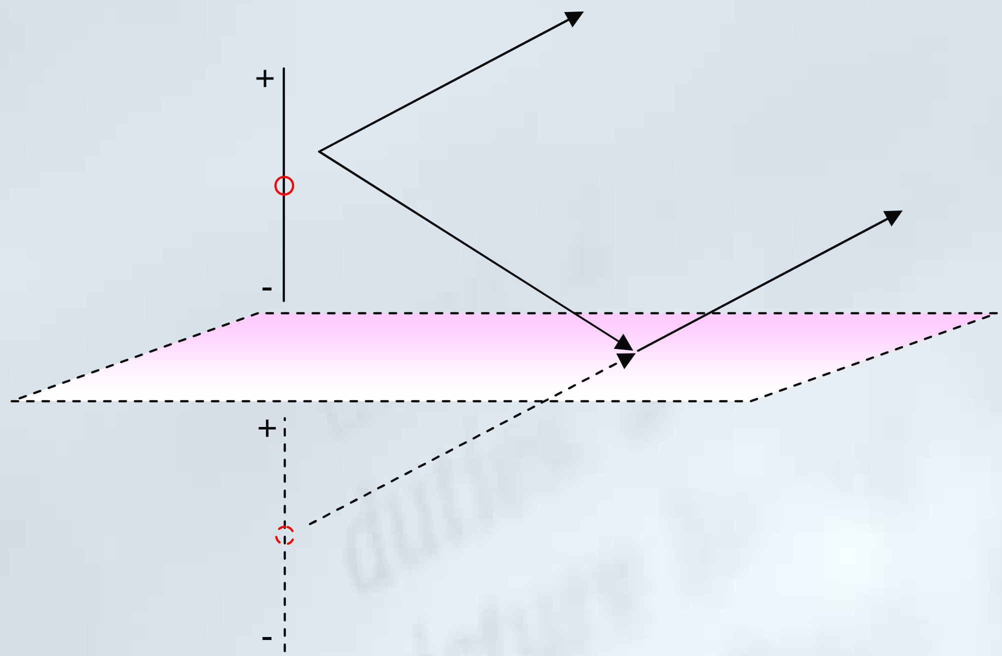
- Ground affects the antenna in 3 ways:
  1. Modifying the currents in the segments due to near-field interaction,
  2. Changing the field illuminating the antenna,
  3. Changing the reradiated field.
- Perfect ground is a perfectly-conducting sheet at Z=0 extending to infinity in all directions (don't we wish).
- The NEC-2 real ground (Norton-Sommerfeld), a lossy sheet of zero-thickness at Z=0 extending to infinity in all directions.
  - Accurate down to about 0.001 wavelengths above ground. The antenna is *not allowed* to touch the ground sheet.
- NEC-4 can model ground with actual depth below ground.
- Computationally, ground is handled by projecting an *image* antenna below ground. Quicker to compute, reasonably good accuracy.

Image antenna

Modeling with simplified ground



Horizontal Polarization
and Image



Vertical Polarization
and Image

Software

- NEC-2 is free. It's difficult to use.
- Interface software provides a user-friendly interface to NEC-2.
  - Capture / Edit the antenna geometry, loads, and sources.
  - Display the antenna pattern, input impedance, antenna efficiency. Frequency sweeps.
  - Allow selecting loads, sources, wire size, etc.
  - Optimization.
- Most newer interface programs also work with NEC-4.

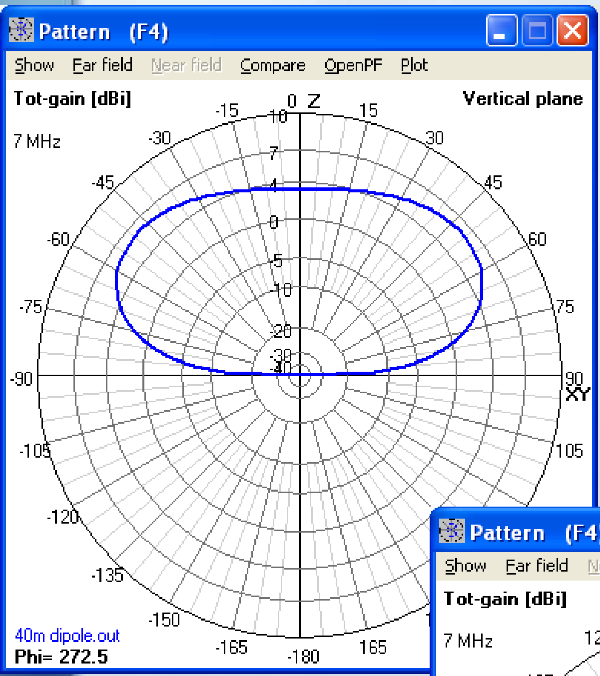
Software

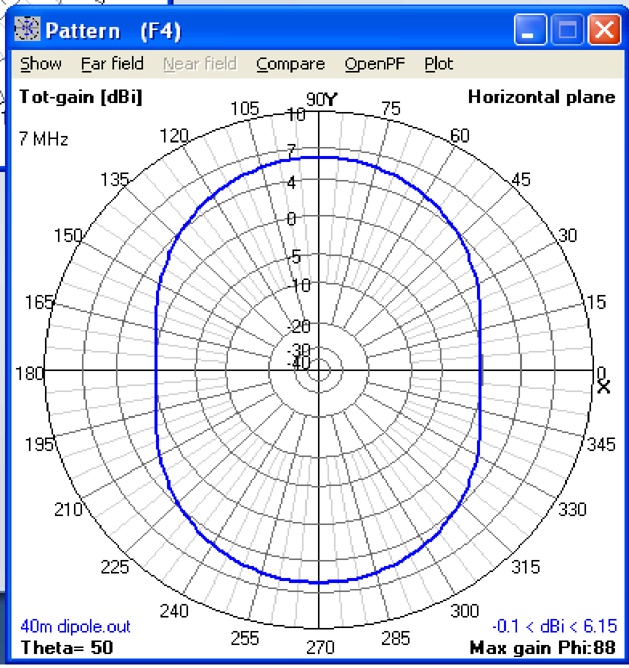
- Free
  - 4NEC2 (standard) and 4NEC2X (adds 3D visualization). My tool of choice.
    - http://home.ict.nl/~arivoors/
  - MMANA (uses MiniNec rather than NEC-2).
    - http://mmhamsoft.amateur-radio.ca/mmana/index.htm
- Not Free
  - EZNEC - http://www.eznec.com/
  - NEC4WIN - http://www.orionmicro.com/
  - NEC – Win - http://www.nittany-scientific.com/

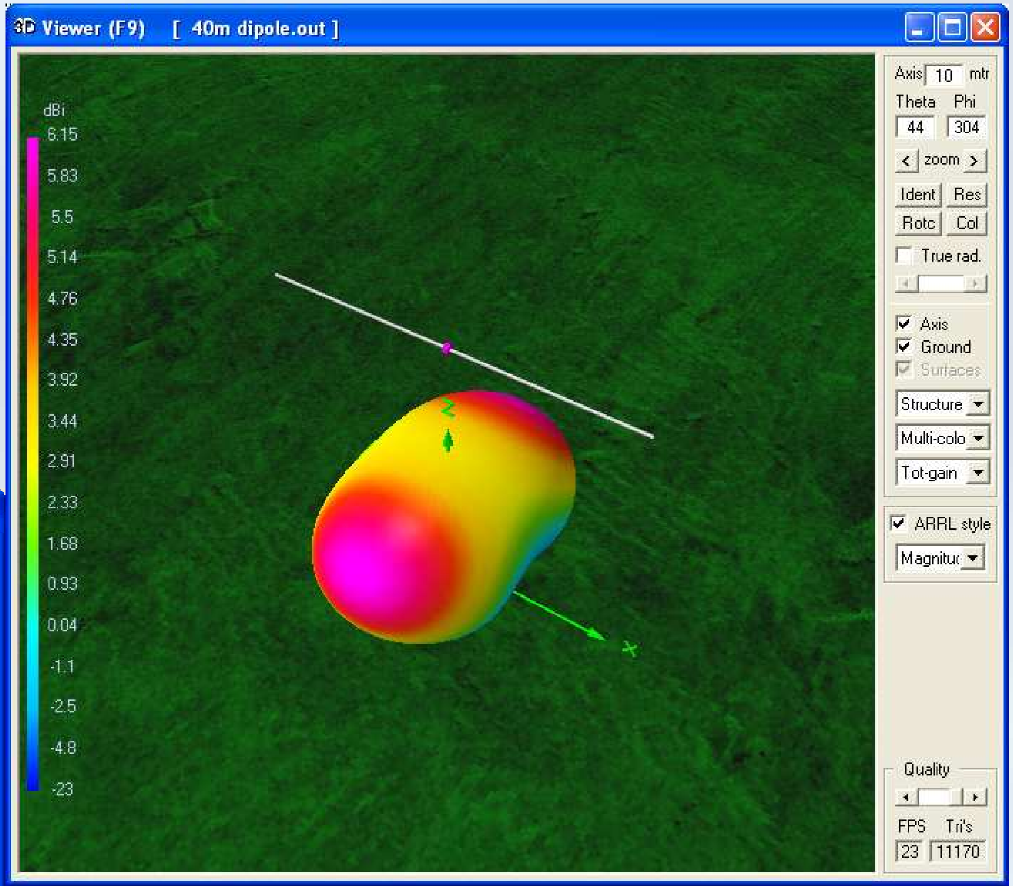
Pattern

Polar Coordinates

- Azimuth & Elevation or 3D



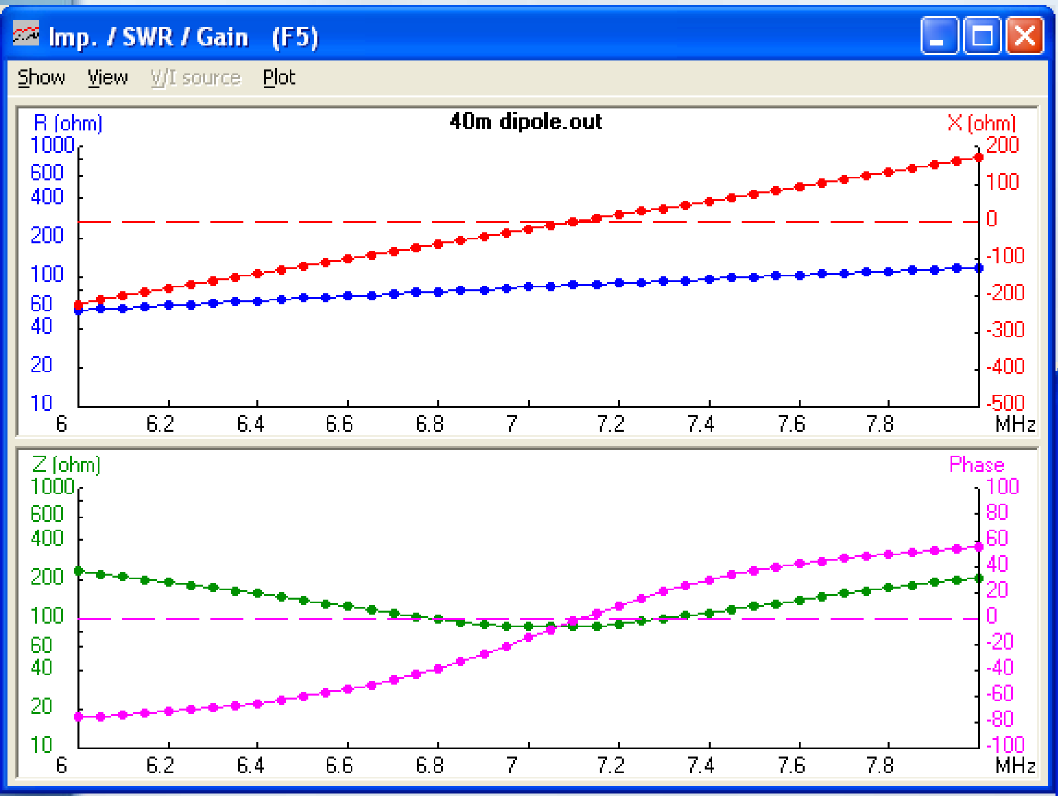


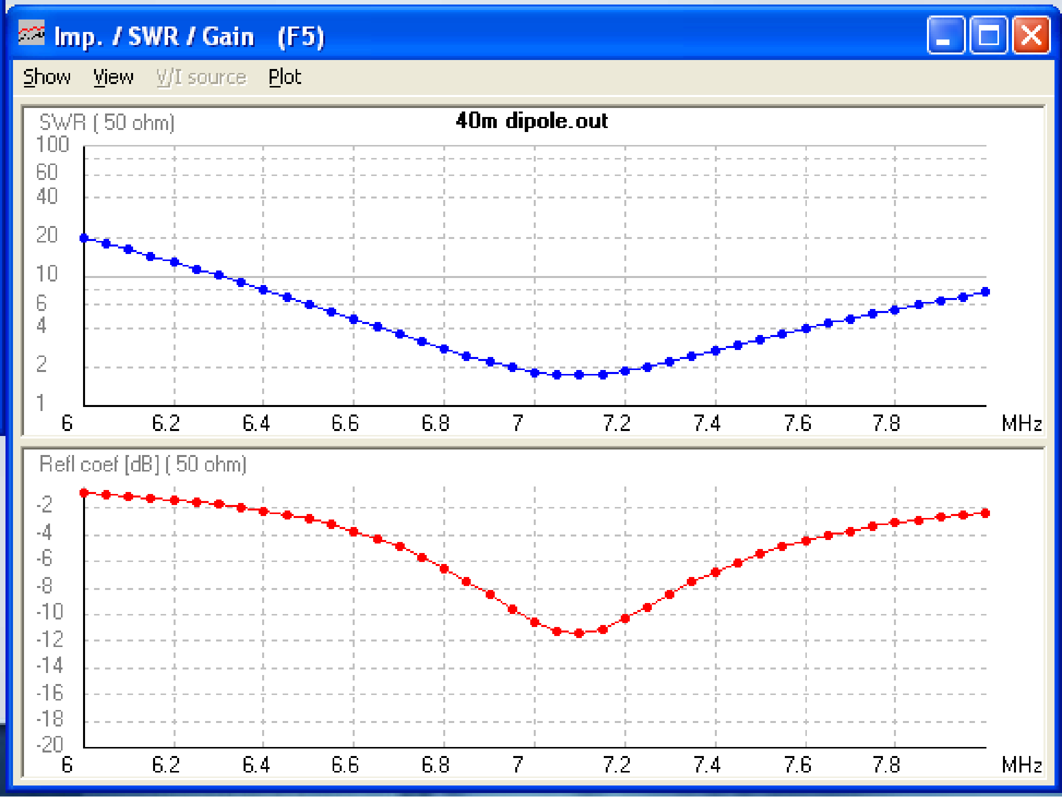


Frequency Sweep

Various ways to show Z_{in}

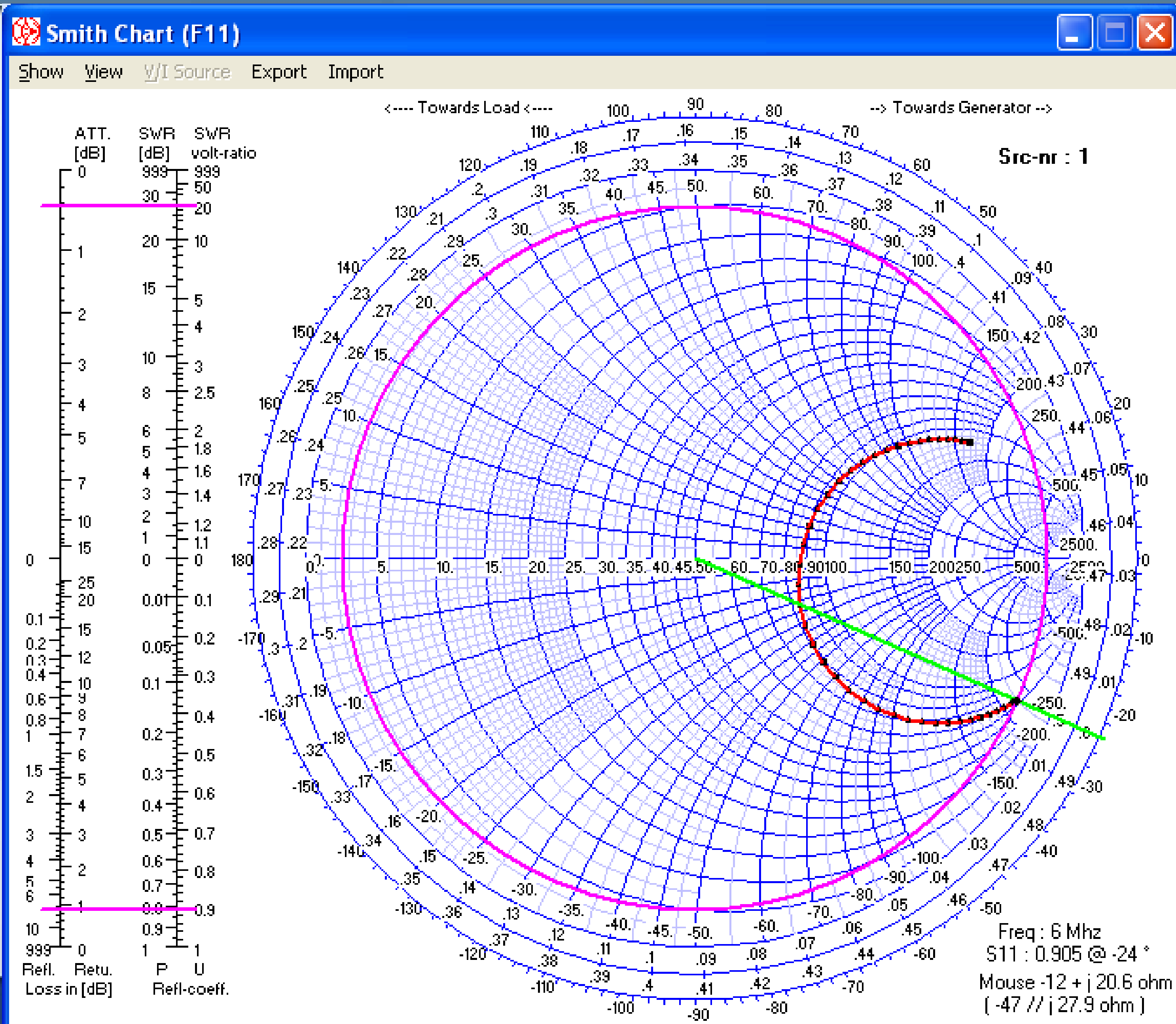
- Z_{in}, SWR, return loss vs. Frequency





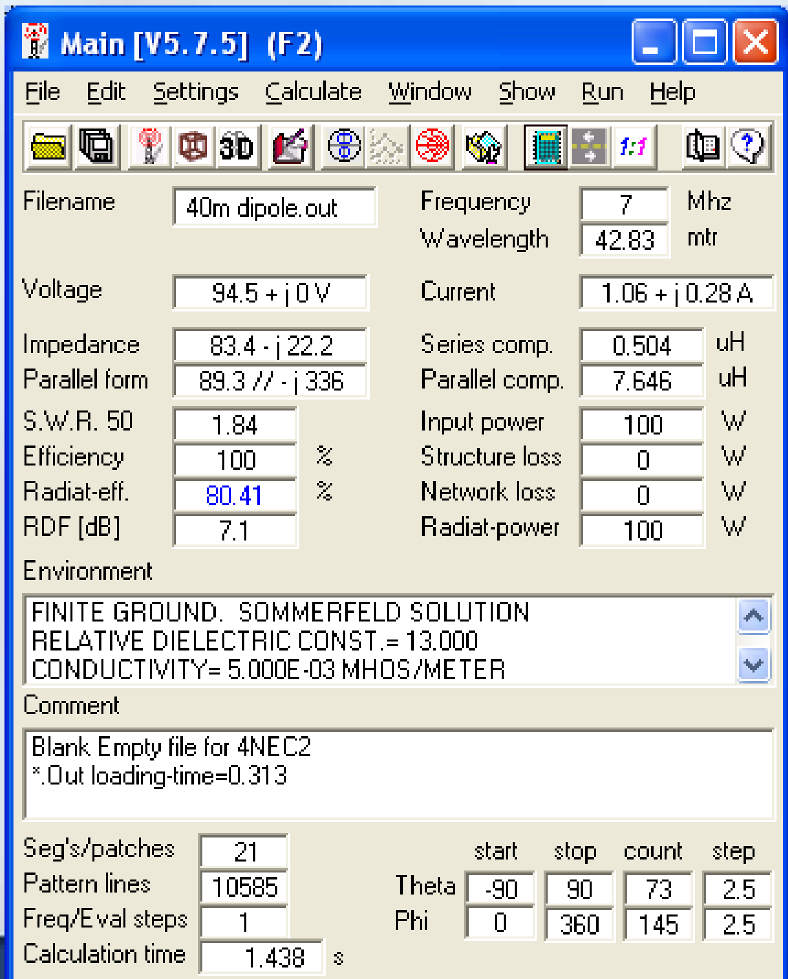
Frequency Sweep

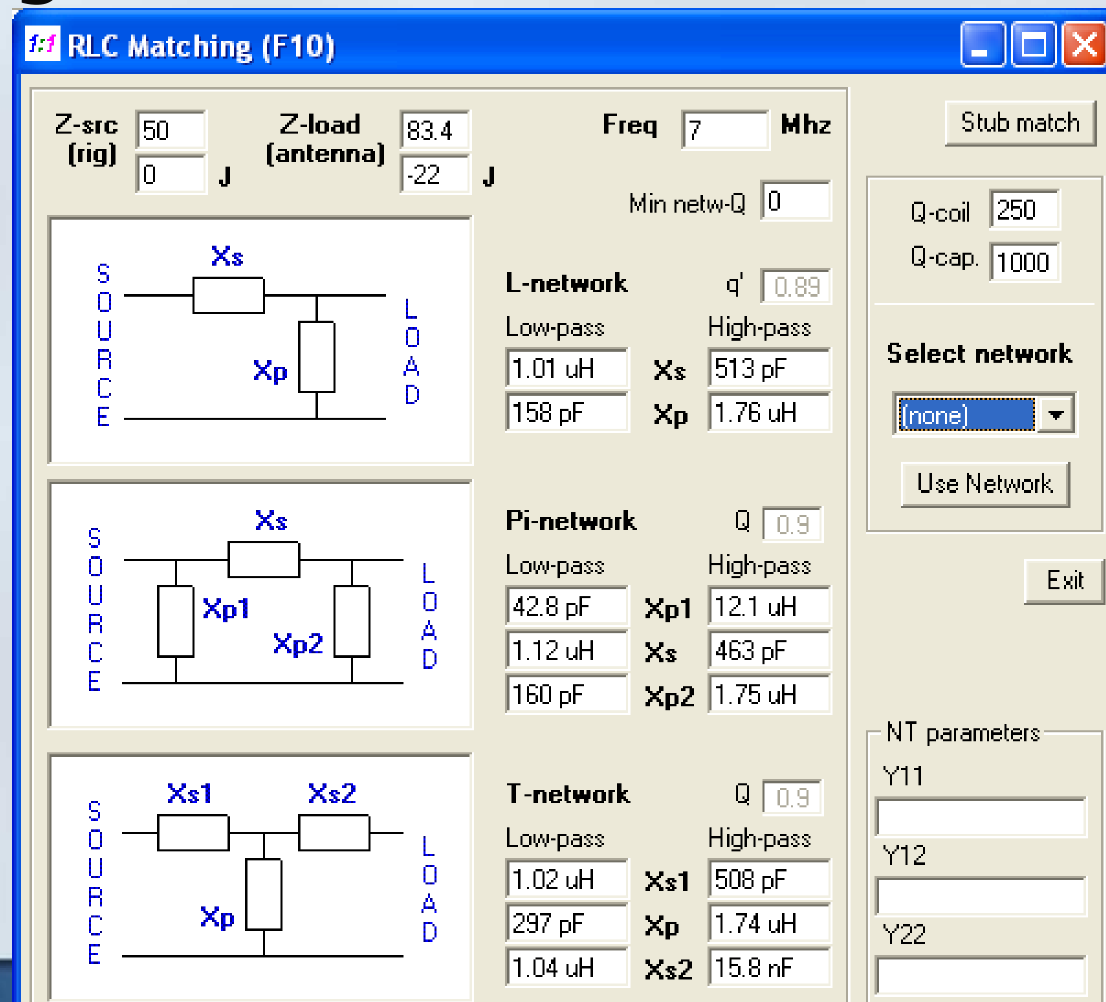
Smith Chart display of Z_{in}



Efficiency & Matching

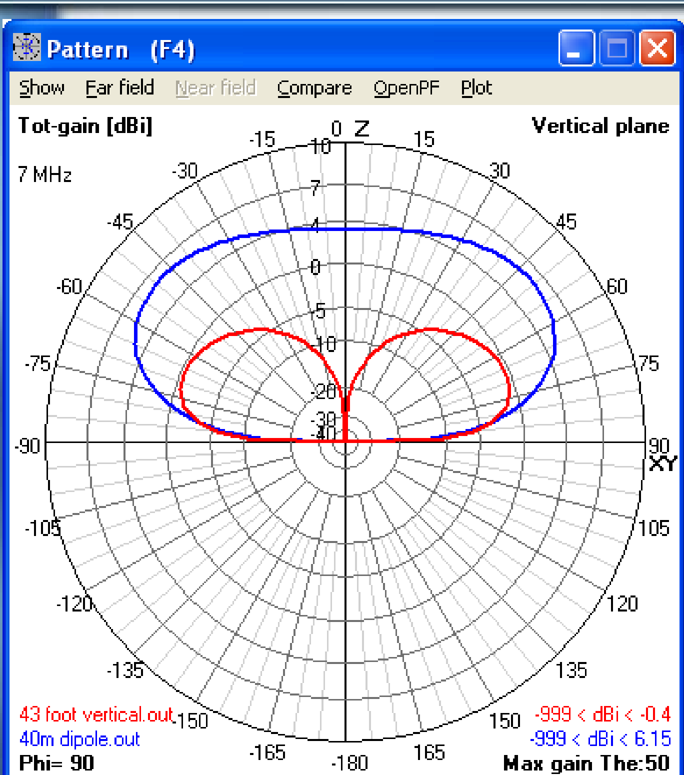
- Efficiency is the antenna itself.
- Radiat-eff includes ground losses.



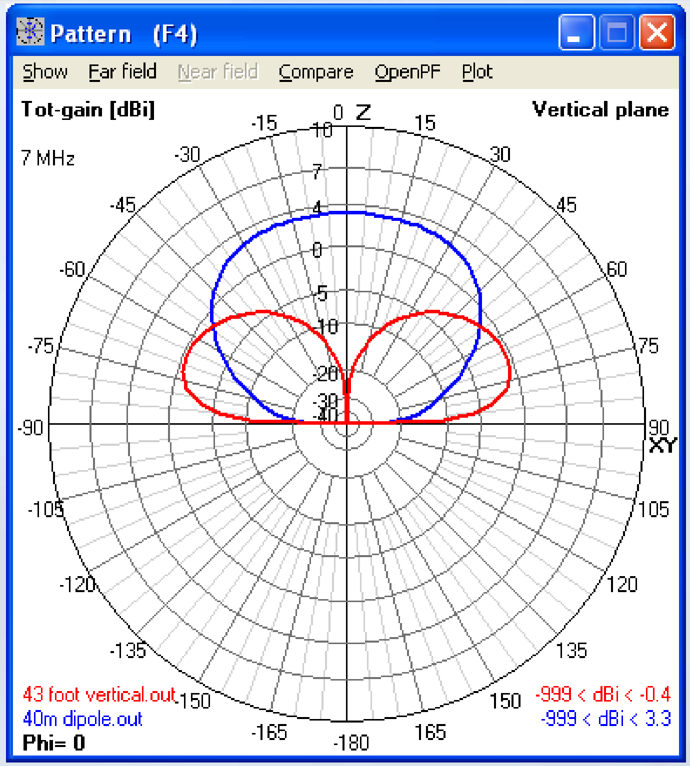


Comparing Antennas

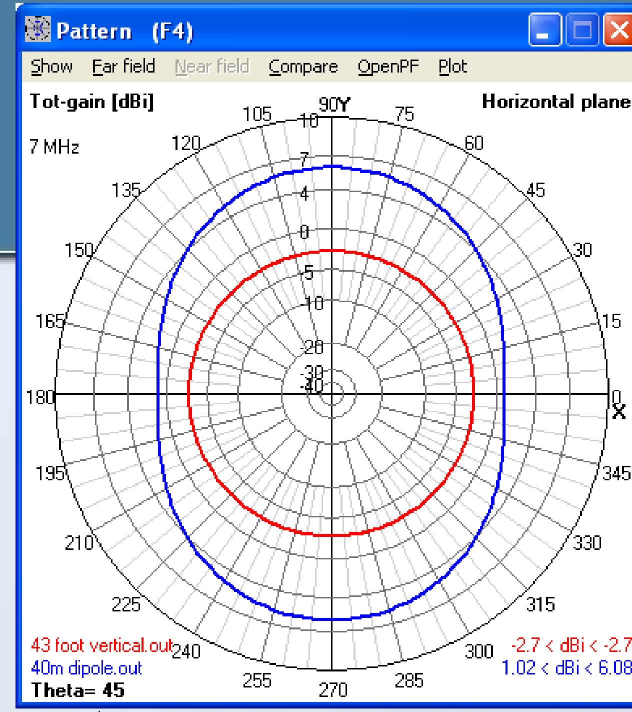
40m dipole at 49 feet vs. 43 foot vertical+32 radials
Real Ground "good"



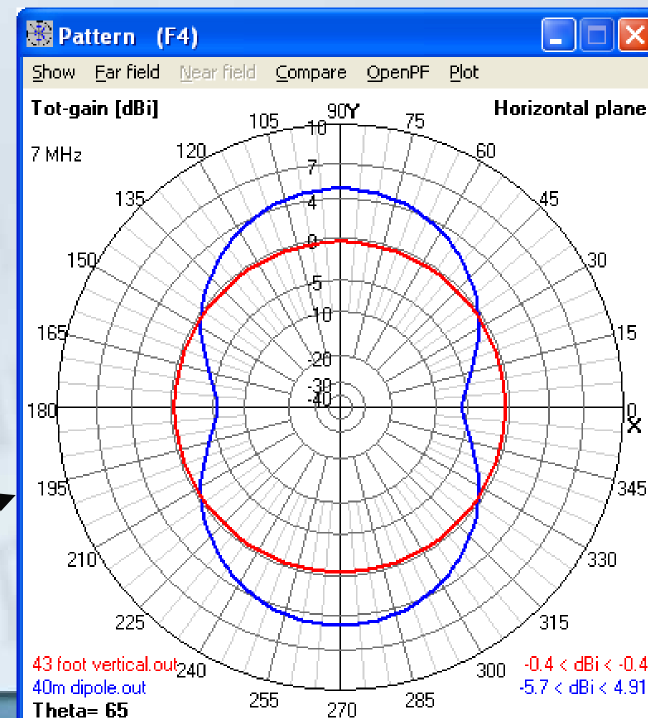
Broadside to Dipole



End of Dipole



At 45-degrees elevation



At 25-degrees elevation
(best angle for vertical)